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Increase of steel surface operational properties by combined hardening

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Increase of steel surface operational properties by combined hardening

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Abstract. . This article examines the influence of laser heat treatment of nitrocementation steel on the phase composition, structure and hardness of surface layers. It is shown that the combined heat treatment of steels – nitrocementation and laser hardening allows to provide high wear resistance of surface layers of steel.

1. Introduction

Mining, including oil and gas, requires a large amount of drilling. Drilling tools - drill bits of various types and designs readily used when conducting drilling operations. This is a consequence of the low resistance of drilling bits as well, and many other parts of the drilling equipment [1-3].

Thus, highly relevant is the development and improvement of technologies of chemical-thermal processing of drill bit steels, which provide improved abrasive wear resistance [3-7].

The impact of concentrated energy fluxes on materials currently receiving attention [8-9]. One of the directions of development of this technology is the laser heat treatment case hardening (nitrocementation) steel, which allows to increase the hardness, strength and wear resistance of the surface layers.

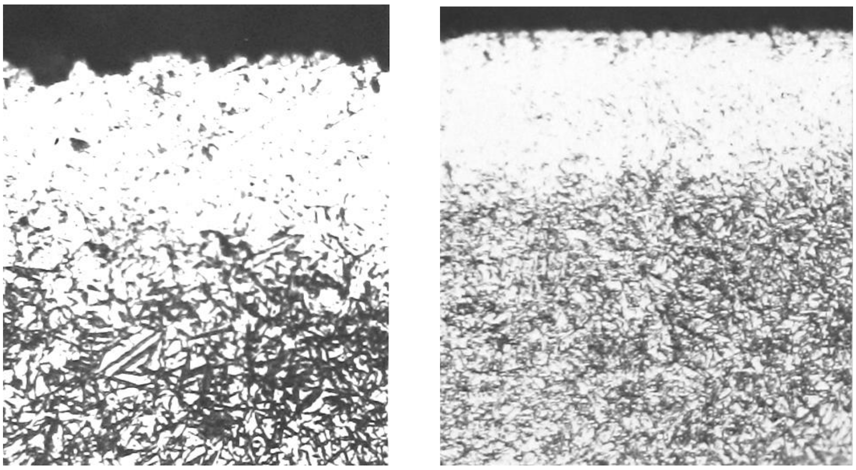
2. Experiment

The aim of this work is to research the influence of laser heat treatment nitrocementation layers on the phase composition, structure and hardness of surface layers of low carbon steel 18CrNi3Mo.

Nitrocementation with subsequent laser heat treatment was subjected the specimens of low carbon steel 18CrNi3Mo (0.16-0,18 % C; 3.4 % Ni; 0.8 % Cr; 0.52 % Mo; 0.43 % Mn; 0.35 % Si; 0.06 % Al; 0.008 % S; 0.012 % P; 0.015 % N; 0.01 % O; 0.01 % H).

3. Results and discussion

In nitrocementation layers with high nitrogen content, especially in obtaining layers with a thickness more than 1.2 mm, the formation of clusters of carbonitrides, oxides, troostite and bainite structures (Fig. 1, a). These structural and phase formation reduces the hardness, toughness, plastic characteristics, surface contact fatigue, wear resistance in conditions of impact-cyclic loading and under conditions of sliding friction. Application of laser heat treatment nitrozomocevina layers without melting the surface allowed to form a structure with high amounts of residual austenite (up to 80 – 100 %), crushed grain, eliminate troostite and bainite structure (Fig. 1, b), improve the hardness, ductility and wear resistance of the diffusion layer.

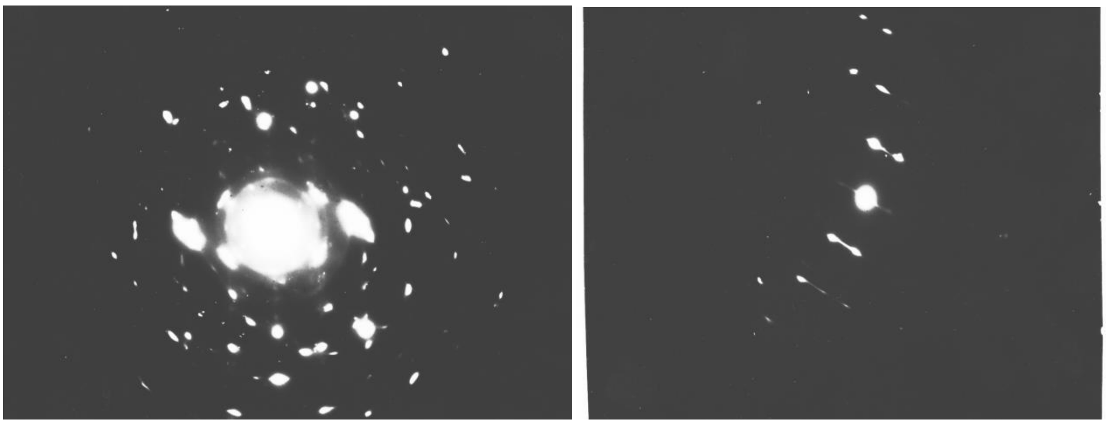


a b

Figure 1. Microstructure nitrocementation layers of steel 18CrNi3Mo (X 400)
a – before laser treatment; b – after laser treatment

In nitrocementation layers with high nitrogen content, especially in obtaining layers with a thickness more than 1.2 mm, the formation of clusters of carbonitrides, oxides, troostite and bainite structures (Fig. 1, a). These structural and phase formation reduces the hardness, toughness, plastic characteristics, surface contact fatigue, wear resistance in conditions of impact-cyclic loading and under conditions of sliding friction. Application of laser heat treatment nitrozomocevina layers without melting the surface allowed to form a structure with high amounts of residual austenite (up to 80 – 100 %), crushed grain, eliminate troostite and bainite structure (Fig. 1, b), improve the hardness, ductility and wear resistance of the diffusion layer.

Study of thin foils made of nitrocementation layers with subsequent laser heat treatment at a distance of 0.15 and 0.30 mm from the surface revealed the presence of a large number of selections of various dispersity and shape. The distribution of precipitates is uniform, their size is from 100 to 5 nm or less.



a) b)

Figure 2. Electronic diffraction (a) and microdiffraction (b) nitrocementation layers with subsequent laser heat treatment of steel 18CrNi3Mo

When the content of nitrogen in solid solution from 0.3 to 0.8 % of the identified region in the form of small ripples. Electronic diffraction and microdiffraction these plots revealed the reflexes of the matrix (Fig. 2).

Analysis of the physico-chemical and physico-mechanical characteristics nitrozomocevina layers showed that the nitrocementation followed by laser treatment has a significant influence on the properties of friction surfaces. From the presented data it is seen (Fig. 3) that the highest wear resistance have nitrocementation layers with high nitrogen content after the laser heat treatment. This is due to the particular influence of high nitrogen content on the formation before the test structure with high strength, ductility, stability and on the kinetics of changes of structure and properties of diffusion layers in the process of testing for wear. In nitrocementation layers with nitrogen content of 0.5 – 1.0 after laser hardening the structure with the content of nitrogenous austenite 80 – 90 % undergoing the process of wear of the $\gamma \rightarrow \alpha$ transformation is not more than 5 – 10 % and has a greater ability to deformation hardening due to wear (Fig. 3).

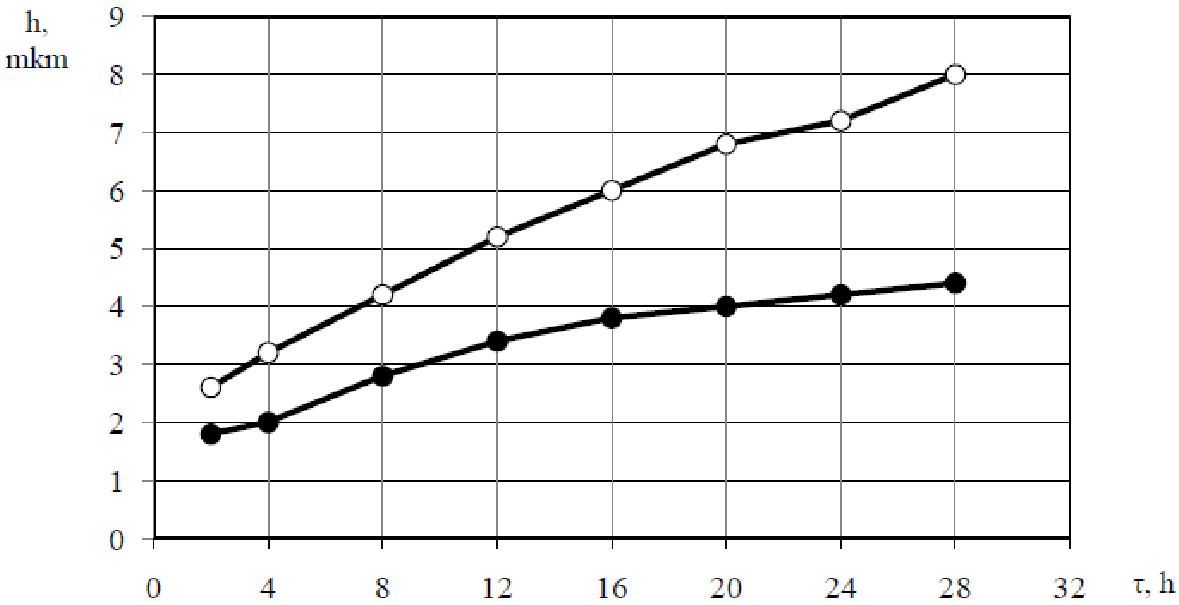


Figure 3. The average depth of the worn hole nitrocementation layers
○ – before the laser treatment; ● – after laser treatment

In nitrocementation layers with nitrogen content of 0.5 – 1.0 after laser hardening the structure with the content of nitrogenous austenite 80 – 100 % undergoing the process of wear of the $\gamma \rightarrow \alpha$ transformation is not more than 5 – 10% and has a greater ability to deformation hardening in the process of wear than the diffusion layer with nitrogen concentration of 0.3 – 0.4 %. For example, the level of hardness on the surface of the wear nitrocementation steel with a nitrogen content of 0.7 – 1.0 % treated laser reaches 1200 HV(Fig. 4).

High level of hardness while maintaining a large amount of residual austenite in nitrocementation steel with a high content of nitrogen, treated with laser, provides a higher wear resistance.

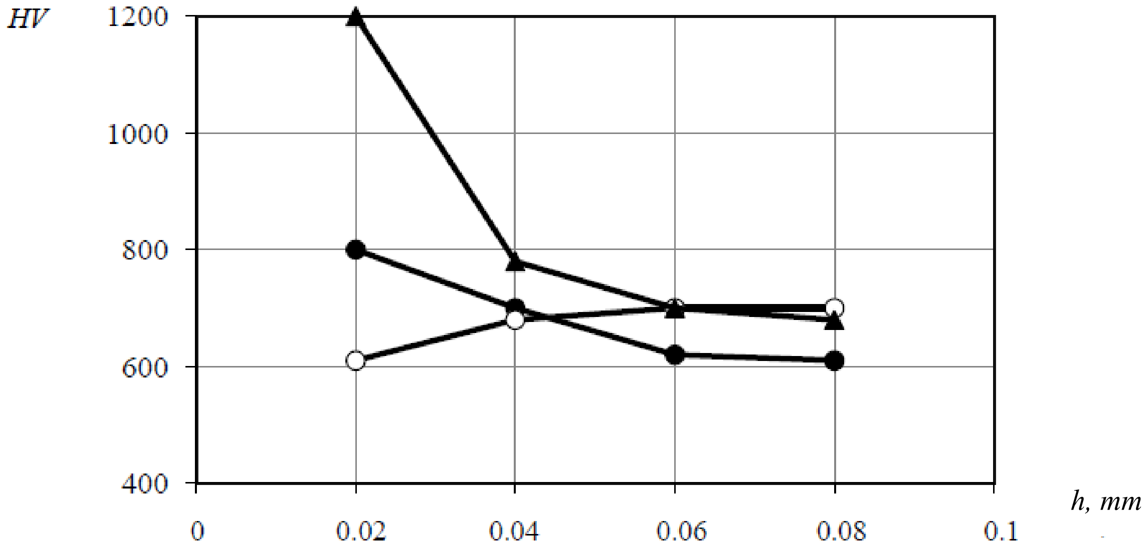


Figure 4. The distribution of hardness in thickness nitrocementation layers of steel 18CrNi3Mo
○ – nitrocementation; ● – nitrocementation and laser treatment (to test)
▲ – nitrocementation and laser treatment (post-test)

4. Conclusion

The analysis of the research shows that combined heat treatment of steels – nitrocementation with a high content of nitrogen and laser hardening allows to form a surface structure consisting of austenite strengthened by fine precipitates. This allows, along with the required depth contact strength to provide good performance properties of surface layers of metal products.

5. References

[1] Shapochkin V I et al. 2011 Effect of nitrogen content on the structure and properties of nitrocarburized steel *Metal Science and Heat Treatment* **52** pp 413–419

[2] Semenova L M et al. 2013 Laws of formation of diffusion layers and solution of the diffusion problem in temperature-cycle carbonitriding of steel *Metal Science and Heat Treatment* 55 pp 34–37

[3] Khokhlov V M 1996 Wear laws at elastic interaction *Russia Engineering Research*. **16** pp 11–12.

[4] Bakhracheva Ju S 2013 Fracture toughness prediction by means of indentation test *International Journal for Computational Civil and Structural Engineering* **9** pp 21–24

[5] Baron A, Bakhracheva J 2007 A method for impact strength estimation *Mechanika* **66** pp 31–35

[6] Bakhracheva Yu S 2014 The Method for Lif etime Estimation Through the Mechanical Properties in Tension *Science Journal of Volgograd State University. Technology and Innovations* **11** pp 27–32. DOI: 10.15688/jvolsu10.2014.2.4

[7] Bakhracheva Y S, Vasilyev A V, Petikova T N 2016 Solution to the diffusion problem in the thermocyclic nitrocementation of steel *J. Materials science forum* **870** pp 545-549 DOI: 10.4028/www.scientific.net/MSF.870.545

[8] Baron A, Bakhracheva J, Osipenko A 2007 Fracture toughness estimation by means of indentation test *Mechanika* **67** pp 33–36

[9] Vasilyev A V, et al. 2014 Valve Cam Design Using Numerical Step-by-Step Method. *Vestnik Volgogradskogo gosudarstvennogo universiteta. Seriya 10, Innovatsionnaya deyatelnost [Science Journal of Volgograd State University. Innovation Activity]* **10** pp 26–32

[10] Vasilyev A V et al. 2016 Dynamics simulation model for the internal combustion engine valve gear *Procedia engineering* **150** pp 312–317. DOI:10.1016/j.proeng.2016.07.017